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TUNGSTEN AND ROCKET MOTORS

SRI Project No. PU-2785
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Washington 25, D. C.

Introduction

This study concerns the use of tungsten in solid-propellant rocket motors and currently involves two main areas of work. The first deals with the erosion behavior of tungsten under exhaust conditions and employs a plasma torch to simulate actual temperatures and gas velocities. The second concerns the thermal shock characteristics of tungsten under nozzle heat-up conditions, and will include a mathematical analysis and correlation of experimental data.

This report covers the work performed during November 1961.

Discussion

Erosion Study Employing Plasma-Jet Exhaust Simulator

Experiments were conducted in the plasma-jet apparatus to determine whether CO_2 would erode W appreciably at temperatures near the melting point of W. The CO_2 was injected normal to the plasma flame through the port previously used for Al_2O_3 particles. The W specimens were "Heli-arc" welding electrodes (W-2% Th). The specimens were positioned perpendicular to the centerline of the plasma stream to avoid the downstream deposition of erosion products on cooler portions of the specimen. Also, the cylindrical surface in the flame provided smooth gas flow patterns and avoided the sensitivity to tip geometry encountered in previous runs with Al_2O_3 in which the rods were co-axial with the plasma. The first run was made with a 5/32-inch-diameter electrode. It was noted that the specimen would be more uniformly exposed to the plasma if the diameter were decreased, and

the remaining two runs were made with 3/32-inch-diameter electrodes. The use of 3/32-inch-diameter electrodes positioned vertically is now the tentative standard for future runs.

The results from the erosion experiments using CO₂ are reported in Table I. The runs were of approximately the same duration and

Table I

EROSION EXPERIMENTS ON W
(CO₂ in Plasma Flame)

Run	Specimen* Diameter (Inches)	Specimen** Temperature (°C)	Duration of Run (Seconds)	CO ₂ Flow Rate (gm/min)	Approximate Specimen Erosion Area (cm ²)	Weight Loss of W (gm)	Rate of W Weight Loss (gm/min)
A	5/32		45	2.49	0.59	0.337	0.448
B	3/32	3250 ⁺¹⁰⁰ ₋₂₀₀ °C	60	2.49	0.36	0.318	0.318
C	3/32		60	4.28	0.36	0.469	0.469

*All specimens were W-2% Th "Heli-arc" electrodes.

**Temperature of front edge just before CO₂ injected into plasma.

temperatures as those made earlier with Al₂O₃. Very appreciable erosion occurred in the CO₂ runs. The W-weight loss was on the order of 300-400 milligrams, compared with negligible weight loss for the Al₂O₃ runs. The very preliminary runs to date suggest that mechanical erosion in itself (Al₂O₃) is not likely to be significant and that some chemical reaction with W will probably be required for significant erosion to occur.

A good deal of time has been spent during the current reporting period in attempting to improve the accuracy of the specimen temperature measurements. A close-up objective which will magnify the specimen image has been acquired for the optical pyrometer and its effects on the temperature measurements are being studied.

Thermal Shock Study

During the past month work has progressed on strain measurement instrumentation for determining (as a function of time) the outside surface strain on the tungsten ring thermal shock specimens. Both electrical and mechanical strain gages are being investigated.

A wire strain gage (Baldwin-Lima-Hamilton Type SR-4) was bonded to the outside surface of a tungsten specimen. The specimen was then

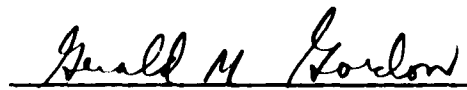
placed in the thermal shock apparatus. The gage leads were connected to a Baldwin-Lima-Hamilton Type N portable strain indicator. The indicator output signal was fed into a Tektronic cathode-ray oscilloscope and the strain was recorded on the oscilloscope during a thermal shock test run. Considerable interference was encountered in the strain output signal due to strong magnetic effects in the region of the graphite heater. The interference was traced to a 180-cycle A.C. ripple superimposed on the rectified D.C. heater current. To overcome this ripple it will be necessary to filter out the 180-cycle signal. A filter is being designed and will be built.

A mechanical strain measuring system is also being built for measuring strains at elevated temperatures. This system is not affected by the magnetic field in the region of the heater. The system is of the "scissors" type and consists of two arms which contact the top and bottom edges of the test ring. The arms are attached to concentric shafts leading outside the test chamber. The arms and shafts are radiation-shielded to minimize thermal expansion errors. As the tungsten specimen expands, the "scissors" are opened, thus rotating the concentric shafts in opposite directions. Outside the system, the rotational motion is converted into linear displacement on a dial gage sensitive to 0.0001 inch. It is planned to photograph the dial gage during test runs to obtain a continuous record of strain versus time. It is also planned to determine the increase in test ring diameter with time by measuring the displacement of a horizontal quartz rod in contact with the outside surface of the specimen. Machining of the "scissors" strain measuring system is completed and the system is now being installed.

Future Work

During the next month, further experiments with CO₂ will be conducted in order to study the effects of flow rate and temperature on W-erosion. Also, it is planned to begin investigating the erosion characteristics of other exhaust constituents and other types of W.

Work will continue on obtaining accurate strain measurements. A series of tungsten rings will be tested in the shock apparatus.



Gerald M. Gordon
Senior Metallurgist

GMG/emk

Approved:



A. E. Gorum, Director
Material Sciences Division